

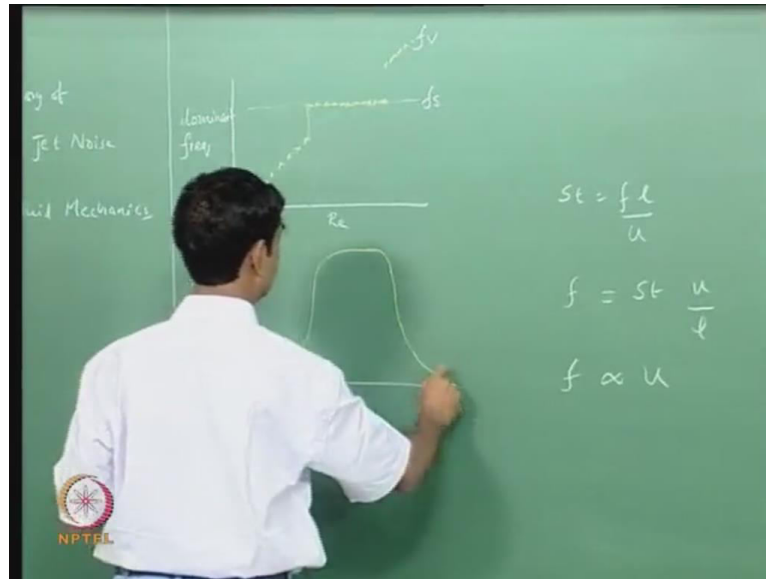
Acoustic Instabilities in Aerospace Propulsion
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Lecture - 35
Role of Hydrodynamic Instabilities – 3

Good morning everybody, we are continuing with our discussion on how hydrodynamics is affecting combustions stability. And then we also looked at how vortex it is a make sound and causes some kind of hydrodynamic noise. And we looked at it in the contexts of solid of the motors. And I was also talking about the lock on between the vortex shedding frequency and the acoustic frequency. And this also similar to the case with flow structure interaction and vortex acoustic interaction and vortex acoustic combustion interaction.

And in this context I wish to give you a reference of a very famous paper by professor how we title contributions of to the theory of aerodynamic sound with application to excited noise. And the theory of flute in general of flute mechanics volume seventy one issue 4 6 25, this, a 673 it is a very big paper almost 50 pages. And it is a very famous paper you see that rockets and flutes they are all behaving in a similar way so little later we will speak about the flute abroad some flute with me. And we will speak about it but talking about the lock on, and we will see if this these concepts are applicable in dump combustors as well.

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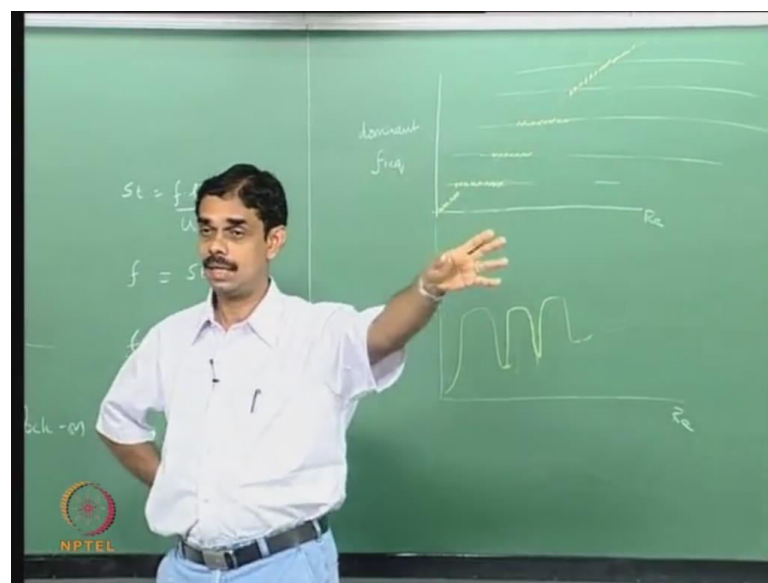


So, when we look at low structure lock on do you look at the dominant frequency that you see when see verses ran olds number and write below I have flout amplitude verses remolds number. And the vortex shedding frequency we saw it is scale by a characteristic straw hall number. So, if you have a straw hall number which is $f l$ over u then f will be equal to $s t$ in to u over l or other f is proportional $t u$. And therefore, frequency will increase with remolds number in general because as you increase the velocity, we will increase the Reynolds number you can plot velocity also here. So, as you increase the Reynolds number usually the frequency keeps going up of vortex shedding but then what happens? So, let look at the case of a structures of it is this is try to a structure like for example, in a case of a cylinder shed vortex but cylinder is mounded on a spring or something. And then the spring mass system also oscillates or another example would be I mean the same kind of situation occurs in under what a cables where you have flow. And then it sheds vortices but the cable itself can move around a vibrate.

So, you come here so let say this is the frequency of the structure so this is f_v equals like this f_s come like this so well so assume increase the Reynolds somebody your frequency comes like this. And it suddenly it locks to this structural frequency and both the structure and the vortex structure will live ate the frequency. And the vortex will start also being shed at the same frequency everything will wall together and then it will go up. And of course, there will be some his studies when you go this way and that way but

otherwise this is the pattern. And the amplitude would be when it will be like this it will generally increase naturally as the velocity is increasing is we get more noise being coming up. But as you approach the lock on there is a sudden rise in amplitude. And then there will be a decrease in the epic of the vibration or the vortex tank covered all. So, if you all looking at a pipe usually you can exited a several modes. So, if you are looking at that soil duct motors or a flute something you can have may be more then when on harmonic. Whereas, some structure it depends e e it may be possible to go to another harmonic and so on.

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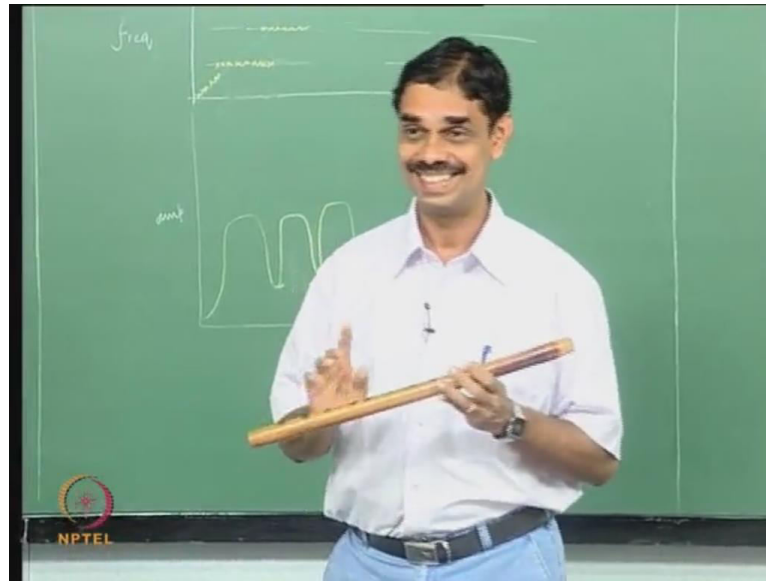
So, if you have such a situation and that is a growth is fighnic so this is structural acoustic lock on I would say sorry vortex structure lock on or it is like flow structural lock on vortex is like flow. Now, if you look at you, we will look at vortex acoustic lock on will have dominant frequency and Reynolds number. And same draw same scale Reynolds number where some amplitude and like a said the same scaling of straw hall number happens. So, f will keep increasing but then as sets increases, let us plot also the these are the various duct modes. If you have you can have a closed open duct or open open dark duct with approximate form less us what is form less flow closed open duct. That you open open duct for the natural frequency c by 4 1 3 c by 4 1 5 c by 4 1 and if you have open and pipe c by 2 1 c by 4 1 over.

So, we just symbolically I do not worry which one it is, but we symbolically mark and they are constant the more in those frequency. And when the, when you increase the Reynolds number and the frequency, it is increasing. And then it will 6 to 1 acoustic more and then it will 6 2 next 1 and next one and may be after that it cannot lock on. So, then it will this climb like this so this is and then the amplitude would be we will exact features it depends on the experiments of. And depends the actually amplitude depends on how the damping is in the system how they depends on the frequency so many other factors. But this is you like a schematically how the amplitude the very. So when have this lock in situation some people call it lock in some call it lock on when that happens you have the vortex shedding frequency. And the tube frequency duct mode so tube mode they will be exactly the same frequency you can measure the for example, what we did some years back maybe it was in nineteen 97 and 98.

So, we measure the vortex shedding frequency vortex shedding frequency behind or request which we are trying to the similar, the in a heat with a rocket motor. So, it could hot where in any one meter and then we are measuring this value of exactly same as the acoustic pressure frequency which we measure in the acoustic flute. Whereas if you did not have this is lock on you will have broad band specter. And there is no precise matching your frequency S and the vortex shedding frequency may be different from it will be quite different from the acoustic natural modes. But when the lock on and there exactly precisely same and you can see to several decimal places and it is like a non-linear interaction. So, any questions beyond some period in some range this locked in and in the beyond that it its it does not occur now precisely how many modes it will lock on how many it own lock on etc big.

It is hard to tell there some cases when in our experiments you have manage to lock on to the 8 mode and ninth mode and tenth mode. But the lower side is because you cannot lock in below this because there may be no acoustic mode, And above that the damping may be much that you get certain driving from the vortex which will try to drive the acoustic mode. But then that may not be sufficient to get the amplitude to go up because the acoustic dumping of these modes will be very high. But precisely how many modes had lock and all that depends on the actual case but in generality it this is what happens. So, we will I brought some flutes with me and some bottles so we look at this and just you get you a idea.

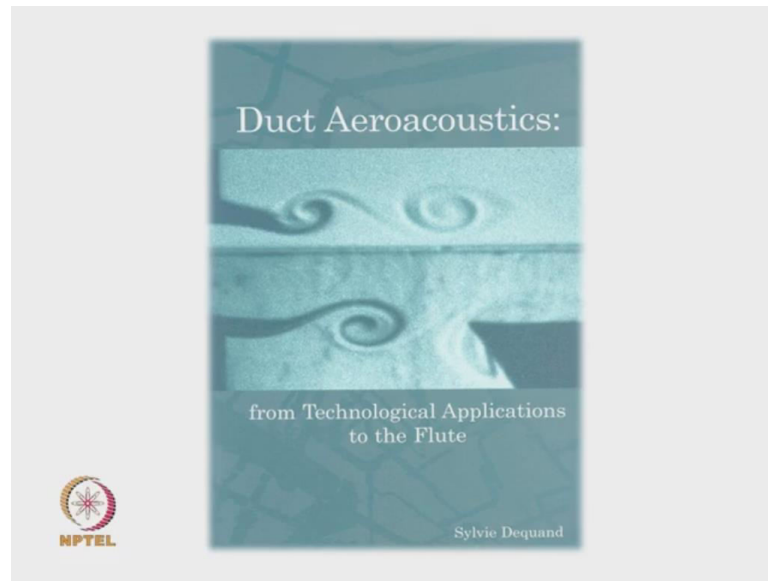
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First, we look at the flutes these are Karnatak flutes mostly. So, you can say it is it has wholes here and it is a strake passage. And of course, there is nothing burning here but the characteristics is very similar to combustor in the sense it is a duct acoustic. And so you excite lock on to the cavity modes here and it is in general clues to the what kind of mode open mode actually where as this is at some other win dent some other clarinet almoner why it a clarinet. So, I do not know how it even looks like seen in twenty from a distance.

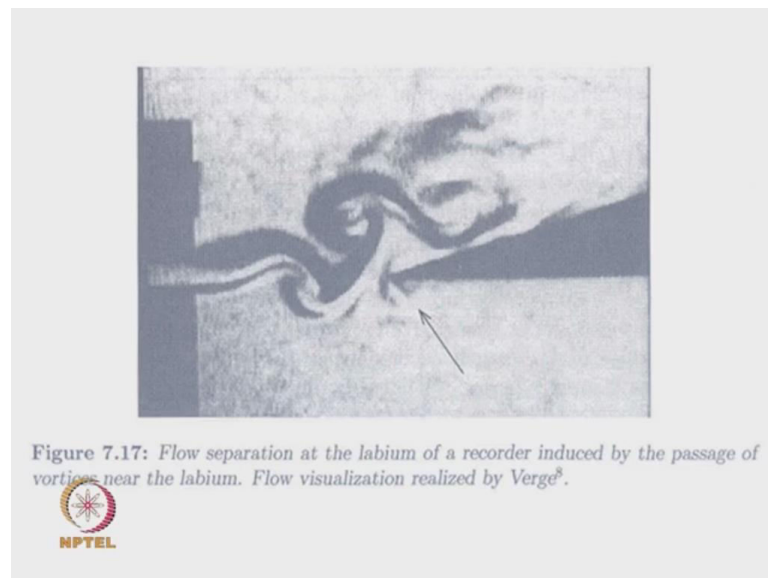
But this one is more like a open open end although you could ten to think this side is closed but there is a hole here. And this here, when you play you keep certain fingers certain way and so the last whole you closed and then that determines the effective length. So, this kind of make the pressure equal to the atoms refresher. So, then the effective length becomes from here to here and open duct mode there will be some slight different, but that is kind of what it is. So, what you do I will blowing if so what you doing I am gracing this. And of course, there different flutes were differently there some other flutes which have a labium like you have reat kind of thing I have.

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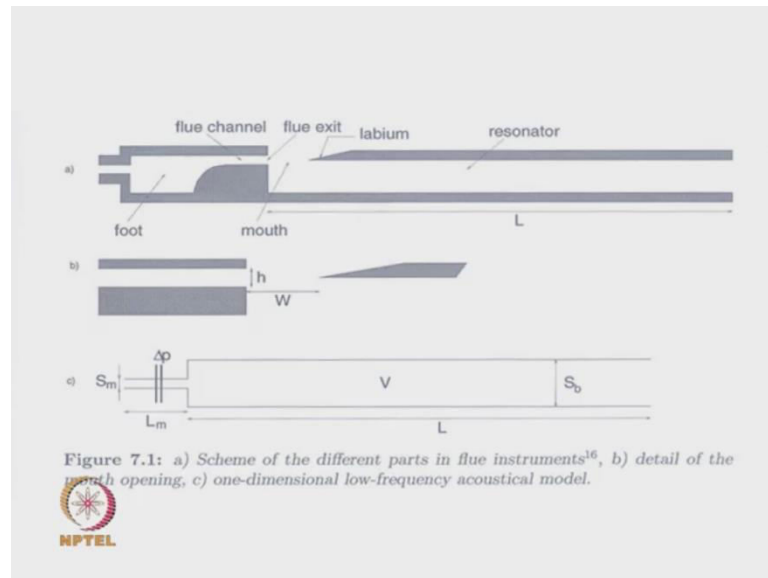
Do you blow this way and then this is a peace thesis on flute. And you have what I mean there is a sharp edge another sharp edge and this vortex comes hits on this that kind of it.

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So, this is another kind of flute with the reed I think this are the ones if you go to the marina beach. And we can play flutes high had one of them but my daughter is taking that and she is not giving me. So, you blow this way and then there is flow goes this way and then it interacts with this edge that that is the way it is sorry.

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But the yes some jet comes out here but I think the interaction is with this edge so e if this is not there the sharp edge is not there then would not make a song. And this is the people adults le run photographs and close places and so on for those thing. And you can see this is like how the vortex is coming in rolling happen and so on so far. I do not want to project light with this because of copy write violation so just show you this books I will. And so the first thing you can notice is let us look at the flute can make out some that this is the short one and this is a big one. And mean you can see if you go to the cenalioc music concept they use some different flutes where as in western music flute they use the same flute for different not sometimes. They use the short flutes sometimes we use big one when do you use big one when do you yah so low a pictures you can use the big one. And because it will have a inversely proportional do you lank that is what you did so. And this is a smaller lengths so will be have frequency and you can we will play s a in this and play s a in this and you can see whether it is actually different.

Let us try to remember that note. So, this is significantly higher frequency I think this is on c shahapen and this is gesus I mean significant different frequencies there and you can also notice that. So, the you move your fingers and that is so you get it, but then had this lock-on phenomena been not there you would have to precisely to get certain frequencies. You will have to precisely blow at some Reynolds number that would be incredibly heart, because you also use the blowing power to increase the volume more decrease the volume also, what you do is.

So, you do not have to be so sharp and that way you can use the little bit of this Reynolds number range I mean to control the volumes. So, it is not like the flute played is critically calculating o k this frequency what is a critical Reynolds' number now he gets within some range. And then when he goes to a harmonic he blows the same note he blows the halter I will attempt to demo this But if you does not work will have adios without. So, let us I mean when pass this critical Reno's number and then I reach this frequency which is harmonic. But I am not like looking at a flow meter or Reno's number meter to figure out this just if you play you will get the feel. And now is anyone who know how to play flute no this type lying let us see what happens we see flow acoustic I mean vortex acoustic lock on happens or not so just make.

So, this like a broadband spectra. So, the vortices by themselves they have some coherence, but play again. So, he is getting a more coherence, but first time because more like a u f so yes. And you can try yes get an idea you have seen flute in concepts but let us get some practice how you yes do not destroy them. And I have one more you are actually north Indian type one, because it has 6 whole the south Indian one has 8 holes you can everybody can practice. And you can record how the just blow u f that is that is good.

So, you somebody would does not know gaming play that that is very good sound. And which we have in this range here outside the lock on range that is enough so, if you so Ganesh is locking how. But if you are having this that kind of sound then I mean you are you can clearly see that a we are having like a a broadband sound as suppose to very toner sound. And we are not locking in and we really need to get the sharp frequency. And our natural frequency will duck they are very sharp very narrow band which and very sharp present runnels speak. And that is what did he is and then one more good thing but flute is it can sustain several harmonics. So, which your wide flute sounds very pleasant now in flute lock in is very good, you can get pleasant sound as suppose to the u f f which you have in a this manual fuel successfully generating.

But in thermo or in rocket you something if you have this coherence and nice tone that is means amplitude will be very loud. In fact when you made this blowsy sound amplitude also loud, but with the nice sound the amplitude sound also loud because putting everything into on frequency. So, you can have imagine a rocket I mean you have very nice lock in and then we amplitude the curd loud. And then of course, this here the

pressure oscillation are few I mean smaller than pass scalars of the order there it is like some arts or one bar some be like that. And then you can imagine thing coming loose and breaking up and so on so. But the same idea can be used to get I mean to analyze and so on what. And the first thing I did start working on the rocket motor instability with inheritor to read this paper and some other papers and then get an idea.

So, I think if you learn about when the instruments I think you can get very good idea what this lock in phenomena. So, e would we say I hope you saw this clear lock in phenomena it also depends on the gracing angle which is what together struggling to get many time and if you blow too less or too high you would be outside the range. So, here we are locking on to the tube mode or duck mode. So, let us look at example that we are lock see the, if there is vortex and if there is something we lock on to some other frequency would you lock on to. Of course, in this case when you tried for a examining the flute sound came you are trying to lock on. Then you do not get lock on but if you do not get lock on it will lock on that is the way it is. So, let me give another example.

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I have brought some bottles here and here we will not have tube modes, but some other modes. So, we can actually e you bal or speaking about the having mores of natter. So, this the hell more slessnated so nature I will I think he derived formula I ask in exam how to derive the formula. But in the movement you can believe that see let us compare leaser up facsimatly similar frequency right I mean I mean similar lance. So, I will

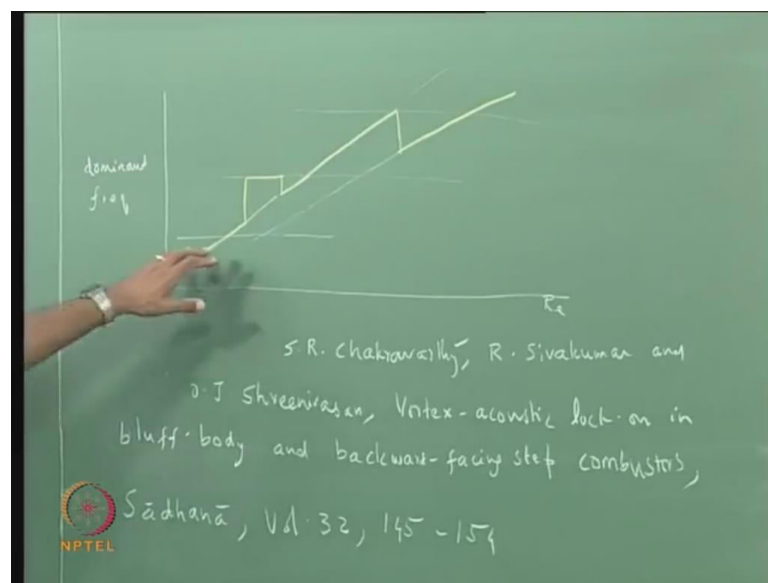
without any formula for hell more resonate all that I demonstrate do not know a small one there was us really small one somewhere no another that I do not know that lance that is all same. So, these little bit difference is there but it should be but you will see order of in differences in frequency. So, let us listen to the flute and let us listen to this so I call it cheat a I should get this frequency that is then it will be if I get pa something then now just look at this frequency. So, this length is I mean I was this as closing till here so it is up a same line is a way to load right. So, there is definitely lot a tune more it is not a see for well your it is have more.

So, here also there is a bigger size means all of one so let me try this small this is definitely small a volume definitely. This is has a higher frequency there you can take all bottles of this one musical instruments. This is even small a there was a increase volume that was increase may rimes number to lock in right. Because I was glowing at the here of line is very softly when I would able to lock on and real I really have to blow much harder. So, because this things frequency is higher so I and the, let us sizes of approximately same. So, I really have to increase my velocity to get to range very a could lock on. So, it is a see this bottle drink some more water to verify the giving more water it is will frequencies come down. So, anything is there to lock in to safe the lock into safe the cavity lock into the frequency the cavity if the, that is what you are having and all on time a just glowing like this.

So, a there is a there is a vortex being shed and the aquatics velocity is in the vibrations are the, this way and glowing purposically and that is when the most power comes out. So, the people are taking movies look that thing a, and this is a very similar situation to a site branches of this is a picture of the site branches. And if you can see this lead in pictures and the wonder how it is lead in pictures in cold flow nominating skill and flow super for and so on. So, they inject a little bit of see you somewhere there d feel so that density is change like it is like putting smoke. But more convenient and to any question on this on this if you have a overtake shading. And if you spring mass system of or some kind of spring an of this system as in structurally you can lock to that like if you have a cylinder. And then cylinder merge spring and merge that system which is study that and that did very well. And the rigid cylinder patterns water kidding patterns frequencies are different from when the cylinder is water down and so on can. And this is interaction between 2 resonation systems.

So, flow structure is interaction them flow acoustics interaction and now we look at flow acoustic combustor before that I was pass. And see any questions on this I thought it was the simple to show thing this that the rather than from right formula like formula. I hope you are the intuit now the next question is what happened when there is a vortex acoustic a coupling in a combustor. So, there is a combustors what are the acoustics coupling would do get this pattern or this would get its some other pattern. So, it is a little take a question in fact people believe that it was the same thing that was happening, but it terms of it there is a another scenario which have a person here recent discovery.

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So, the vortex should happen somehow several modes so let us go to more theory. So, you can simplify the same mode vortex you can have several modes of vortex shedding. So, more check and more and if you have a cavity with I can have one vortex always like 2 vortex always between them and solves and there many modes them. And for you have this that back frequencies here collects a so the, we can actually have of course, both the, that modes. And the when the lock not there on you will see you can see if you make microphone measurement the vortex schedule and the that mode. But then when lock is actually the dock I mean acoustics lock vortex shedding its simply. Because I mean the actual details am not clear there is a new finding the vortex is causing the periodic thing. And the acoustics is probably changing boundary condition that all they to lock on to this.

So, this is reported by IIT Madras people so instead of the vortex frequency locking acoustics here the fine lock vortex frequency and I will tell you when it happens. And then it was happened a this is S R Chakravarthi is a very famous professor IIT in Madras in term of acoustics. Actually you can also see this kind of this situation combustors the one pulse combustors they have follows there is I think some of you seen the one in a ramble and there actually the fuel in that is right behind the black body. So, it is not premix but a it gets premix very fast is like that industrial combustor. So, since the holes are very closed we actually equally equalization fluctuation has closed and equalization fluctuation actually go like the acoustics feel. So, then the thing shift the acoustics feel where is in this experiments actually I think this fuel is injected the, that the way up. So, by the time is the, a the fuel as mixtures reaches the flame the equalization fluctuations are kind of near down.

So, it actually the so vortex is a strong periodic thing and then soundless wave going to towards that. And the prescribe way of how I mean the natural frequency change it can must the, because the it while the lock on happen the impedance are change happens I do not know the details. But a, but now you see this scenario and this scenario and different combustors. So, with this I just briefly mention that you this paper I can have a I can give a pdf. I just mention this is very briefly to flow that still this is very reason finding 2007 actually and so exiting subjects this is lost to be that end. There is a 214 and references to the references to be write in that which given in that review paper. So, if any other questions so if there is any no questions I will mention briefly about passive control of this vibration so, vortex cohering related on the periodic heat release. And can be minimize by manipulating the changing the acoustics reduce the share the acoustics feel.

So, if the share laid is responding the acoustics fuel and is rolling at more to inherently. So, we can some more damping that acoustics feel which some passive devices some damping this periodic role of an all that if its coherent it strength is comes down. So, then the certain of instability will be will be low up. So, what people do is to either put all the faces of string in the duct or put dampers are hell more rented or cot way tubes a when you have a at a location to pressure maximize put a have more recanted to something to that it up of lost then the imagine. So, that is one possibilities so and then other possibilities that you can make mutual the hydrodynamics. And vortex have different

frequency vortex should happen on frequency which is have other way from the hydrodynamic feel. Now, we if issue are this boundary and if you we can in keep the hydrodynamic frequency lower than a acoustics But once you have an so here whatever you do may you may shifts on this way on other way.

But then if not the first mode or second mode or third mode where will get excited so if their far then I think that is the simplest things to do. And the amplitude skin adjusted by adjusting the long length thing then the out that length. So, if you change the outer length if you change the combustor length you can change the frequency of the acoustics feel. So, that the, another way to manipulating the frequency acoustics feel if you change the England by meter and step by meter. The then you can actually change in the frequency the vortex shedding but the problem is when you are made all the combustor. And then the designer would not a change any of this then only possibilities of we have to put just damping devises a now the, another possibilities is to.

Of course, we can damp we can also the change the driving if you again somehow get p prime and q prime out of the face from rumbaing a episode comes starts rate like where. And enterprise is the starts somewhere and the cannot get out the gravity and then the solution was change the gravity of constant. So, a in starting you can say whatever want but in reality it is very difficult. So, here so you can I think it is a got as a since you can actually change the face between the heat release and the pressure.

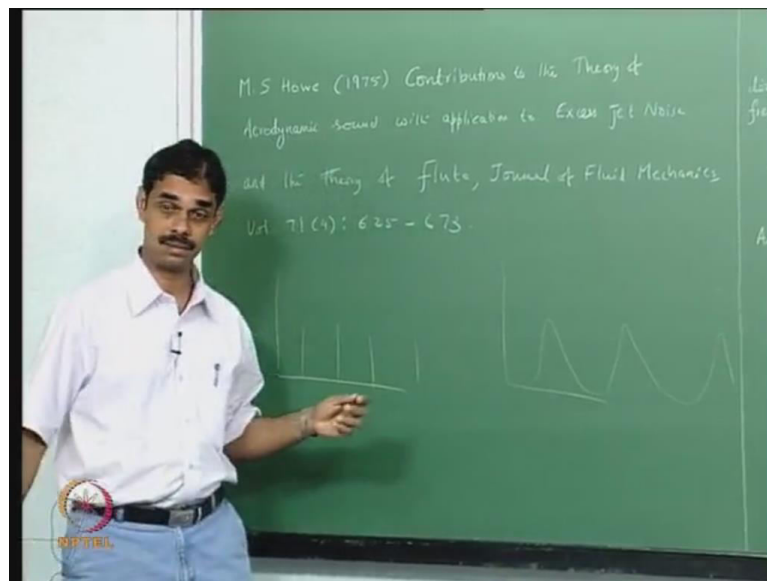
So, you can change the mixing time by different injection n strategies or you can change the location of the flame by changing the velocity is with this the some conduct is the conducted or you can change the fuel injection pattern. And if it is a if you having actually that spray and then you actually change the if a normal you can change this spray and the size distribution of the drop less coming out that are coming out. So, there is some things that is under your control of course, many times you calculate something. And you thing should go this way and when you go other way things, they works.

So, if you have some idea I would try the opposite thing as for just they see which is what say you little to be a honest .And then give a explanation after words that is to get faster solution to get. If you talk about and the combustor when you several burn it as a mention somebody I think somebody ask this question and then you can have each of them having a different delay. So, that we do not have a cohering bang but you have

distributed heat release is that the heat release is neared out oblations near out. So, any questions on this the lot of there is passive control. But in this or somehow that let you write down on these things meant can drink an some water.

So, let us summarize whatever well, let us to a demo thus no interpret it just here or there I am I think I should dressed my flute playing it is of 20 years of some played. I take it out every year for the acoustics class and then go back and then deposit it safely but yes try some other note. So, there was you just get the notes or its harmonic I mean or whatever is the other duct mode it is know in between you can get if you uff then everything is there the non lock on situation then you get a broad band thing. So, there the spectra will be like it will be still modulated by the if natural mode but if you look at the 2 spectra's.

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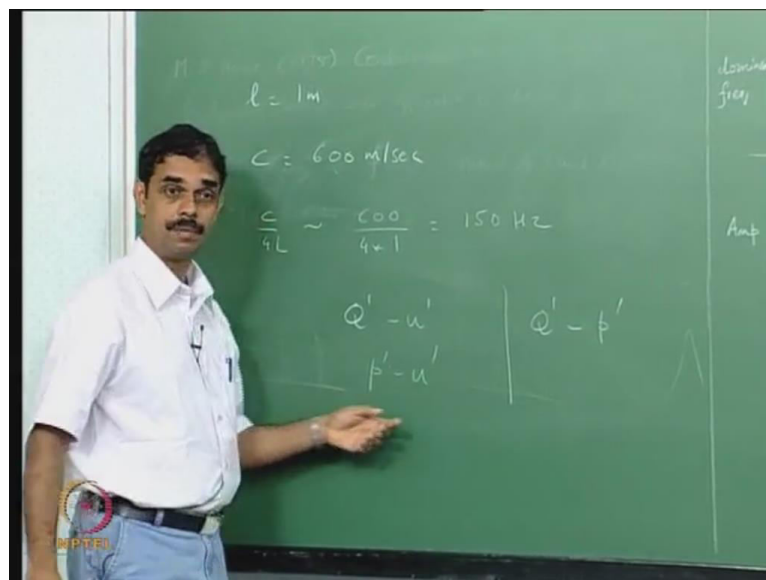


Then you, have a tone you have a sharp frequencies, but if it is not a tone the spectra would look something like this the power verses frequency this is our look like where as if you So, if you make that uf sound this is what we get and nice vortex nice sound from the flute would be something like this and typically there you are 10 harmonies and so on but in between thing you have to change the ab modes. So, then if you have locked on here and you want to get in between thing you have to change the length by moving your fingers. So, you are locked on here r see in this situation the frequency will continuously change because you are as locking to vortex shedding mode. So, here if you increase the

frequency it will yes it will keep on increasing frequency then it will jumped to another mode and keep or the other way.

But where as in this kind of situation where let say your injection house are near the step or something. And then you have locked on here and you keeping this in the flow rate or the rain olds number. And you would not change the frequency sometime and then it will appropriate attempt to I have a mode. So, once it locks still it gets out and it is a big kinds and then it will lock to the next one. So, here also I mean here frequency changing but it not same it is large amplitude under this frequencies. Actually same as that of flute on a combustor this long you will get the frequency this, let us o k the speed of sound will be different. So, let us look at a combustor which is 1 meter long.

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So, l equal to 1 meter and average speed of sound let say like 600 meter per second, because its is a higher value. Of course, in reality we have to solve that problem which is solved there in year to know the temperature. You have to solve the, I gain value of that vessels some equation was there or numerically find it. So, c by 4 l let say it will be like and if you will have dump combustor and the induct is small. So, it will be like a closed end acoustic closed end six hundred divided by 4 into 1. This will be how much 150 Hertz read I did correctly. So, it is of the order of 100 Hertz's 200 Hertz it of even 50 60 Hertz's see frequencies not porter which standing it is the amplitude whether you which stand. So, for example, here I am playing you know some frequency I have its like 400

something Hertz's or something perhaps and it nothing happen to it. And some other flute I am at played 250 Hertz's so 270 Hertz's nothing happen.

So, if the amplitude is small any frequency is, but if the amplitude is large it is the problem. And the other issue is there anything your combustor may not breakup, but something else in their craft or something will have the natural frequency at this frequency then there is a problem. But if that does not happen if that is ensured that those frequency is different than it is a question of how large the amplitude is or certain frequency there is a tendency to be driven. And then you can change the combustor frequency and that is for the, what if the driving can occur in a certain frequency range. You make sure that the combustor frequency is out of the range is these question is any question any how restate your question in some other ways.

So, that I understand so yes I mean if you if there is no problem in structures you can have frequency. This is good example know nothing your flute break up with this frequency and this frequency is amplitude then there is a problem. So, it is does not break up. So, but the problem is if you I mean we want light weight and do not use material and all that. And if you to make it if you make it like big and fat then it will structurally with stand but then you do not want to do that also that is a problem, So, I think is a any engineer will not accept that solution to make yours engine robot by making a massive. Or some I think you would ask the combustor engineer to reduce the amplitude somehow frequency yes you will ask we change the frequency if something else.

So, you let us say you have a low amplitude oscillation some missiles have heard you have well this is recorded. So, I cannot give the names, but so you have a missiles it is working fine o or rocket. Its working fine in the static that is no problem and it is fired also find no problem and goes into service but if the missile is there service every now. And then they will take over the missiles and fire just you check if it works or not it is like shooting practices like if you are a soldier. You have to do shoot so many rounds per week or some sets of guidelines. Similarly, just to make sure that the weapon is working that will be tested right. And then you tested and then suddenly it will blows up and then you panic and one test another one like and it blows up.

And then you go back to test and then make a test the, without flying and everything is fine the oscillations are all most nothing then it turns out that the oscillations are very small. But there was some component in the navigation system which is also it which the, vibrates and spoiled an electronic is very sensitive to sound rate sound and vibration. So, under search then the easiest way is to rather than kill the oscillation already they are very low I knew anything you will change may actually make it bigger.

So, change the natural frequency of the navigation system so that it does not vibrate this. So, under that circumstances or you change the combustor but in a existing combustor what would you let you change anything actually use the designers are saying do magic. But do not state anything so at some magic border into I getting in to stop or something but it may be rocket in to the But so, in this case it is easier to change something if the way the electronic some the change the frequency of that does that is that what you ask no.

So, we are not really change like changing in the combustions frequency is not indicating the lot of the isolations. But they round about wave and your oscillations are low but something else as a looking in anything else. So, in some body in the last 2 3 classes, we will looked at instability will associated with formation of large scale vortices in the mixing layer which couple with the acoustic pressure to excites strong oscillations yes. And we look that co flow results and we so that the we are having a calving harmonics in stability and in the we looked at some brief theory. And we see the linearly stability theory predicted straw will number 0.0 and seven at the initial layer, but then those vortex merging and so on. And then at the this a big vortex and the which is the which is having a lower frequency and it has like a straw number based on they diameter. And they velocity at the exist and that is like a point tau 5 to 2.5 that is the preferred mode exits that frequency then as a good chances. That is the vortex will becomes very coherent and a oscillations will be exited very large amplitude.

And then the combustions gets periodic along with this vortex shedding. And although the in go flow you do not see very large amplitude unless there is this kind of Exton kind of business or or a lock in kind of business. But when this reaction happening that is a very strong mono poseurs so periodic heat release happens to this feedback and the mixing layup curves of in the vortices is where combustions occurs. So, if you have dump combustor and you will just blow air you will not hear anything. That is why in

flute they have that labium and the vortex rolls up from there and heats on the edge and makes this makes a sound and the energy release. So, when the mixing rolls up into vortices and combustion occurs and we will now then have a start having the energy release being periodic in nature. And this will reach maximum and vortices breaking a down in to find more scale turbulence and the combustions now suddenly happens. And so, there different mechanism this leads to transition and I told you it is a very advance topic.

So, vortex interaction is there interactions of vortices with walls is there and so given in harmonic also instability make come. But this is also this flapping mode instability we are so look that flame interaction and that causes the flame wrinkling and so on. So, in any case the lot of mechanisms all lead to fluctuate the heat release which if it is a face with the heat release rate will lead to why which if it is in phase with the acoustic pressure will lead to large amplitude.

So, that is acoustic driving now this goes by the validity here so on way to control the oscillation passively will be to change the phase. That means you change the time delay somehow or you change the location of the heat release zone that way your changing the impedance. You have a certain phase between velocity the heat release and velocity but this also a phase between velocity and pressure And what matters would driving a dumping is the phase between heat release and pressure. I hope you understand this in many of this processes you have q' and u' and phase.

But what you want this to look at the phase between q' and p' . And so you can change that by the changing phase between p' and u' that can be done by moving the flame to a different location where the impedance is different p' over u' is different. And that is another strategy to do torque control which is why the flame location is a very important by fluctuation parameter.

So, you can change the geometry we can put dampers or you can we have a host of mechanisms to actually passively control change the length can diameter or keep this frequencies away. So, I will stop here with this and next class, we will take a look at the very briefly and what is this active control of combustions stability on similar combustions. And then we will after there will speak a little bit over sold of a motors and stability there and if time permits little traffic motors.